# CRITIQUE AND EVALUATION

# of the

# ABAG MODELING SYSTEM

William Goldner,
Consultant



Association of Bay Area Governments

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## INTRODUCTION

This working paper is written to serve several purposes. First, it is meant to provide an overview of the ABAG modeling system as it presently operates. Second, as an outcome of continuing in-house experience, the operational modes of the system are identified in order to clarify the purposes and objectives of using the system. Third, a discussion of the problems and shortcomings of the systems will be undertaken. Finally, a set of recommended adjustments, refinements, and system modifications will be itemized.

This paper supplements several other descriptive segments which together describe the current status of the system. These include a description of the computer program and its structure, a catalog of the input requirements and parameters of the PLUM program, a comprehensive documentation of the demographic model (APPLE), and a preliminary draft of the Base Employment Model (BEMOD).

## SOME PRELIMINARY OBSERVATIONS

There are several observations that are in the background as this paper is written and it is useful orientation to the reader to make them specific. They are in the nature of underlying assumptions to this evaluation.

First, the ABAG system is operational and contained in-house with personnel trained to operate, evaluate, and modify the system. This means that startup costs have been absorbed in the past, and the costs of modification are not burdened by the learning and initiating processes than occur on any system.

Second, models and systems in general are representations rather than mirrors of reality. As such, they focus on the important variables and omit those thought to be of less significance to the conceptual framework. The justification for using computer models lies primarily in their explicit expression of interdependence among variables of interest, as well as their speed in synthesising these interconnections for large number-crunching exercises.

Third, the ABAG modeling system is built around a counceptual framework that uses assumptions to bridge uncertainty. Therefore, the outputs are approximate rather than exact. Emphasis has been placed on the concepts of statistical error ranges being applicable to all model and system outputs. Uncertainty is inherent in the system in several forms:

1. The zonal system incorporates zones of varied size and content;

2. The data base reflects data sources that are inexact, or estimated, or approximately defined;

3. The parameters and structural relationships contain an incomplete catalog of causal forces and variables;

4. The computer program reflects programming conventions and statistical approximations that are subject to measurement and estimation errors;

5. The particular scenarios of assumptions that propel the system are less than perfect reflections of the policies that the system is simulating.

Fourth, the administration and operation of a modeling system involves a team, a group of technically qualified persons with complementary skills. The mechanism that allows everyone in this team to understand the operation of the system is up-to-date and adequate documentation. Documenting every modification of the program, describing changes in the data base, justifying the changes in underlying assumptions, are not easily transmitted verbally or, if kept in the mind of the person making the adjustment, easily forgotten. Documentation is a mandatory part of large-scale system's operation. It also contributes to transferability of the system to other locales and supports the acceptance of the system's outputs by those who use them or are affected by them.

## Modes of Operation of the System

When the system is used, the objectives of the analysis vary. This flexibility is a useful attribute of the system, and broadens the range of uses. On the other hand, there are limits to the uses to which the system can be applied. An explanation of these types of uses can therefore provide insights to the operational modes of the system.

The ABAG modeling system has been used in several ways which fall into three categories: (1) descriptive modeling; (2) policy modeling; (3) prescriptive modeling.

Descriptive Modeling uses modeling techniques to project a future state of the region starting with present conditions and applying a package of specific and feasibly attainable assumptions to the variables that control the operation of the system. The earliest uses of the PLUM model for the Bay Area Transportation Study (BATSC) were of this mode. Subsequent use of the modeling system, identified as Series 1 Projections by ABAG for the Bay Area Water Quality Control Board also constituted descriptive modeling.

Policy Modeling uses comparisons between alternative runs to measure the impact of policies that are reflected by varying the inputs to the system. For example, a concentration of basic employment may be emplaced in Santa Rosa zones as a reflection of a policy to reorient the economic development to the northern sector of the region. The system-wide impact of this policy is measured by utilizing the differences between such a policy run and a comparable run without the employment increment in Santa Rosa. Tests of locational impacts of

airports, major industrial developments, enlargement or contraction of development lands, are examples of policy testing that characterizes this modeling style.

There are several problems that intervene in this modeling mode. First, some policies do not translate themselves to input variables that guide the system. For example, land and housing prices, interest rates, the general price level, and their fluctuations are outside the direct scope of the system. Second, the system's conceptual structure may not be sufficiently sensitive to policy changes. Sometimes the scale of the policy change is too small to affect the range of outputs; in other cases, the conceptual linkages between the policy change and the measured impact have been imperfectly designed.

Prescriptive modeling is primarily a process of emplacing (prescribing) target values of one or several variables into specific zones and allowing the model to balance out the accounting that reconciles these overriding values with other variables and other locations. This is the most recent application of the modeling system as used in Projections '79. Much of the input to these types of runs are estimated or translated from local jurisdictions' prescriptions. These estimates are emplaced by hand and therefore involve the development of simple utility programs to supplement the main stream programs of the system. Although intervention into the system can take place in any of the models, the most important prescriptions have involved BEMOD and PLUM, the allocation models.

The major uses of prescriptive modeling are to reconcile target values from local jurisdictions with those of other jurisdictions and with regional control values. In addition, the reconciliation also involves congruent matching of population, employment, and land uses. This mode is particularly valuable for identifying spillover effects from one jurisdiction to another, and inconsistencies in local quantitative goals between jobs, housing, population, and land available for development.

## The Structure of the ABAG Modeling System

The modeling system consists of four main models which are augmented by several satellite models and utility programs. The main models are:

1. ABAG Population Projector and Labor Estimator (APPLE);
2. A regional economic projection model;
3. Base Employment Model (BEMOD);
4. Projective Land Use Model (PLUM).

The Demographic Model: APPLE. APPLE is a conventional demographic model using the cohort-survival methodology to project the region's population forward in time. Birth and survival rates can be varied to modify the age-sex structure of the population projections. Provision is made in the model for separate processing of military, group

quarters, and migrant population. Migrant population is disaggregated between employment-associated migration and retirement age migration.

APPLE is documented in two volumes. The first is a description of the cohort survival method as used in the model. The second is a detailed documentation of the computer programs and explanatory flow charts and diagrams.

Unfortunately, the computer tape containing the program was destroyed. Therefore setting it into operation anew would require the punching of cards and assembly of the program from the documentation. In addition, the technicians who designed and operated the program are no longer in the agency, so that a relearning of the operational procedures would be required to generate updated and revised demographic projections.

The Regional Econometric Model. This model is not documented in detail, and therefore most of the characteristics of the model have to be obtained by word-of-mouth and even by hearsay. The model consists of a system of equations in which national projections (BEA ) drive the regional variables. Most of the units flowing through the model are in terms of employment, and at the regional level, two-digit SIC industrial categories are linked to the national projections. Some industries are particularly questionable. For example, construction is assumed to maintain a constant level from the base to target year. Also, models developed directly out of employment trends do not explicitly exhibit labor productivity changes--an important element in regional economic development.

The output of this model is reconciled to the demographic model's output by hand adjustment so that a "reasonable" margin of unemployment links both models. Varying assumptions regarding birth rates and net in-migration were the basis for alternative projection scenarios, so that it can be fairly said that the demographic model drives the system. The contribution of the economic model then becomes the simple function of defining and quantifying the region's industrial structure.

Base Employment Model (BEMOD). The spatial allocation of basic industries is the most difficult modeling task in the system. This is due to the too general nature of some industrial location theories, or the too specific and unique characteristics of others. BEMOD is virtually undocumented; the early version of the model developed by Joseph Nathanson has now been substantially changed; the present operational version of the model is explained in disconnected fragments.

Control totals from the regional econometric model are assembled into industry categories which are purported to have the same locational patterns and respond to the same locational influences. Fourteen industrial groups are identified for BEMOD allocation. These 14 regional control values are partitioned into SMSA control totals and the SMSA controls are projected by a modified shift-shares process to reflect an SMSA-specific pattern of changes in the industrial structure. Within SMSA's, zonal employment allocations are made on the basis of a weighted combination of variables in each zone: vacant industrial land,

developed basic land, employment by industry. The weights are the coefficients of regression equations fitted to each of the 14 industry groups.

Provision is made for emplacing unique locators into zones on the basis of known information gleaned from exogenous sources. The SMSA control total is adjusted downward when this occurs, leaving a smaller residual to be allocated. The employment allocations are adjusted to the SMSA control totals to maintain consistency with the SMSA and regional employment projections of the econometric models.

Land on which basic employment locates in each zone is absorbed in conformity with zone-specific land absorption coefficients (employees per acre ratios). These coefficients do not distinguish among the 14 types of industries in the employment allocation. Land absorption is limited to vacant acreage zoned for industry. If land is available in less than the quantity required for the allocated employment, the employees per acre ratio is assumed to increase.

The employment allocations from BEMOD are transferred to PLUM, and become part of the "drive" mechanism by which PLUM executes its allocations.

Projective Land Use Model (PLUM). The PLUM allocation model locates population, housing, local-serving employment, it accounts for the land absorbed by these activities, and balances the various categories of acreage available as their uses change through time.

PLUM operates by adding a development increment to the already developed base in each zone. It operates presently in five-year increments, but can operate on any time scale from one-year to a single leap from base to target year. Each increment is driven by the zonal allocations of basic employment from BEMOD and subject to the whole list of regional control totals on population, employment, and housing units.

The summary step-by-step process is as follows:

1. Zonal basic employment increments are processed by an allocation function (the lognormal distribution) to zones of residence where they are identified as employed residents.

2. The market served by local-serving industries is made up of existing employment at work-place (reflecting the location of business services demand) and employed residents (reflecting the location of demand for retail trade and services). As a first approximation, the increment in basic employment allocated to residences is taken to reflect the residential portion of this demand. This becomes the basis for locating local-serving employment. The increment in local-serving employment is then added to the basic employment increment and this total employment increment is allocated to replace the

first approximation mentioned above. All employment is now in place.

3. The resulting allocation of workers to residences determines the locations of residences, subject to the availability of land. Any zonal residential demand in excess of the land supply is reallocated to the nearest zone with available land. All residences are now in place.

4. Acreage required for local-serving activities, for streets and highways, and already determined for housing and basic employment are added to the developed categories and taken out of the available land supply. All land is now accounted for.

5. Satellite programs to generate zonal distributions of household income, and housing structure type are executed at the end of the program.

6. Incremental quantities of all zonal variables mentioned above are added to the base year zonal data, updating the complete data base to the target year.

7. The target year data is processed as if it were the base year and a new increment is generated to the next target year.

The PLUM program has been continuously modified to allow external information to be added to the allocation process, either influencing or absolutely overriding the outputs produced by the model. Examples of these exogenous zonal overrides are:

(1) developed land restored to the vacant available category;

(2) residential density overrides;

(3) local-serving land absorption coefficient overrides;

(4) acreage taken out of one category of use and added to another to hold it for future development;

(5) streets and highways acreage adjustments;

(6) local-serving attractor overrides.

## PROBLEMS WITH THE ABAG MODELING SYSTEM

The ABAG modeling system has never undergone a wholesale revision since its adoption in 1972. Instead, changes and modifications have been made on an ad hoc basis in response to problems which have emerged from the uses which the system confronted. As a result, developments that have

emerged in other planning agencies and research centers have not been amalgamated into the system. In addition, many of the changes that have been made to the system have been adopted without testing and under the pressure of time constraints. More permanent tested versions to replace these quick and dirty repairs would result in substantial improvement to some parts of the system.

In the following discussions, shortcomings of the system are discussed under several headings. First, there are a list of design and conceptual improvements which, with proper testing and calibration, would allow the system to operate with greater conceptual integrity. Second, there are a number of operational and programming problems which should be investigated and revised.

Design and Conceptual Problems

There are several operational concepts and frameworks that exist in regional modeling systems that provide guidelines for comparison and even for possible adoption into the ABAG modeling system.

The Econometric Model. The current state of the art in regional economic modeling has developed far beyond the elementary concepts that are used in the economic model. Although criticism is difficult to express in the absence of any documentation, there are several concepts in the modeling structure that are below acceptable standards. Most serious is any dependence on the shift-shares method of projection. This procedure has been severely criticized in theoretical and conceptual terms and also in practice.

In addition, the whole framework of the economic base, where it exists in the modeling system, should be carefully reviewed and overhauled if it cannot be exorcised. Especially critical are the need for partitioning of individual industries into export and residentiary components, the identification of portions of retail trade that serve visitors to the region, and the recognition of services, especially office services, as an important drive mechanism to the region's economy.

Regional models that drive systems of energy-economic models of energy demand may provide one source of revision of model structure. In addition, new sources of data that are useful in spatial allocation are at hand, including square footage of structures of various types.

Finally, the adaptation of input-output from national and state levels down to the regional level has been the basis of some experimentation. However, the process of transformation of the more comprehensive national I-O models to the regional level has been subject to extensive and persuasive criticism. [Richardson, 1978, and Miernyk, 1975].

The design and implementation of a flexible disaggregated regional economic model that is well documented, easily operated, and has adjustable parameters would be an invaluable addition to the modeling system. Such a model, interactive with a demographic model, constitutes

the "drive mechanism" that propels the system into regional futures compatible with varied assumptions. With a well-articulated "drive model", a whole range of satellite models can be designed for special purposes to accommodate program requirements. Energy demand models, disaggregated by appliance type, or related to enclosed space, can be built out from the economic model. With appropriate industrial disaggregation, satellite models for expressing special features of office industries, or high technology could be designed. These special industry analyses should relate to labor requirements, occupational skills, value added, and spatial and locational characteristics.

Socio-economic disaggregation. Disaggregation of the workers and households in the system would allow more sensitive allocation than the present treatment which assumes each job holder, family, and resident is an equivalent entity. Disaggregation by income levels internal to the modeling system would be far superior to the partitioning by income at the end of each iteration. If possible, income and race would reflect an even greater range of behavioral differences.

Income stratification would require some concentrated model design work in order to be incorporated into the system. The model by Putman at the University of Pennsylvania is operational although the detailed documentation involves a careful review and interpretation of the computer program. The ABAG income files are resources of special value in this potential model revision and their existence would justify an approach independent of the Putman version. The regional economic model would be the starting point for income disaggregation, providing regional control totals for each income stratum of workers, and a conforming stratification of households. The worker strata could be allocated through BEMOD and PLUM and the incomes collected in residential zones. Here, the income level requires a construction of family income levels, constituted by transforming workers to households. Households by income (the demand side of the housing market) would be matched with housing units by sales or rental value (supply side). The excess demand for housing units would be reallocated to other nearby zones in the same way as the overallocation operates presently, but within income/rental strata.

This ideal and possibly incomplete sketch would certainly require some simplification, but a feasible and operable path could be programmed with appropriate assumptions to bridge the hairier complexities.

Land use - transportation interaction. At present, the system allocates workers, population, and householders subject to constraints reflected by the availability of various strata of land. These allocations assume that congestion and barriers in the transportation network will not constrain development. However, a standard concept contained in the available packages of transportation analysis models includes capacity constraints on the network of highways. These capacities may be of great significance in affecting the allocations, operating to impose a second set of constraints on the allocation process.

Two-tier allocation system. Presently, the system of models allocates to 440 zones. These zones are, in most cases, groups of census tracts and in some cases individual tracts. Zones vary substantially in size, measured in area, population, housing, developable land, and other variables. It would be desirable for zones to be delineated more homogeneously and the number of zones to be decreased. This would constitute the zonal system for the first tier allocation. In those cases where finer zonal details are required, a utility program to reallocate to census tracts should be designed as a second tier. This refinement could also be integrated with the presently used algorithm that allocates zonal outputs to subregional study areas and local jurisdictions. For sketch planning uses of the model, allocation to the first tier would be sufficient and also more economical.

Land use sequence. The model's sequence of residential land absorption operates within each zone even though the development potential in other zones may be higher. This follows from the definitions of primary and secondary developable land that are used in the data base. Prime land is acreage zoned for development and with infrastructure present or committed. Secondary land is zoned as developable but subject to constraints because of steep slopes and other hazards, or with capacity constraints with regard to sewer, water, and roads availability. The model allocates residential development to an individual zone and within that zone uses primary land initially and then, if more land is needed, uses secondary land.

Given these processes and land definitions, actual real-world development is likely to occur on prime land across all zones before any development occurs on secondary land. This process should be tested for its effect on the allocations and incorporated into the model program if feasible. It should change the spatial patterns of residential development significantly.

Local-serving algorithm. The allocation of local-serving employment is very unsatisfactory and a completely new algorithm should be developed. This modification should incorporate data from the Census of Retail Trade Major Retail Center (MRC) publications. The data on center size, returns to scale, agglomeration of retail functions, and purchasing power should be incorporated into the revised model. Provision for substantial overrides and hand-emplaced activities should be included to allow unique locators to be added to the allocation. Continuing real world concern for several of the disaggregated categories warrants the separate modeling of local government, education, health institutions, and local office industries in addition to the present breakdown of retail trade, retail services, business services, and the residual of other local-serving.

Central city headquarters and office industries. Based on the ABAG Economic Profile Report's emphasis on the office industry, provision needs to be made in the modeling system for the treatment of office employment in a fashion that is semi-independent of the industrial classification. This process should start with the regional economic model and be carried through BEMOD and PLUM. This could be adapted to

the capability of a regional input-output model, and also could involve an allocation strata in BEMOD. In addition, provision for emplacement of office unique locators would enhance the overall allocation pattern.

BEMOD conceptual framework. At present, BEMOD operates by allocating to control totals generated for SMSAs within the region. The shares for each SMSA for a specific industry category are determined by a shift-shares model operating on the regional control totals from the economic model. In effect, locational competition for industrial sites is within SMSAs rather than across the region. This may be a problem especially when a large unique locator is emplaced in one of the non-central SMSAs. If the unique locator uses up almost all of the SMSA share, the small remainder is allocated by BEMOD allocation weights over all the other zones in the SMSA rather than affecting the zones in other SMSAs. Because of the tendencies for some industries (say, electronics) to view sites outside of Santa Clara County as possible locations for new plant locations, it seems desirable for competition to be regionwide rather than within SMSAs. This could be accommodated within the system by abandoning the shift-shares and SMSA controls in BEMOD and allocating across all zones in the region. This process would also be more consistent with the concepts of the two-tier approach mentioned in 3. above if that modification were adopted.

Operational and Programming Problems

Sequential allocation. Although the conceptual framework of PLUM calls for the simultaneous solution of the equation system, the allocation process programmed for the computer operates sequentially through the zones in zone number order. This generates some particularly bad allocations, especially when zones become filled and overflows have to be reallocated. In addition to the problems generated with regard to zonal overflows, the matrix of commuter trips which is embedded in the program is seriously flawed by this issue. The distortion can be illustrated by following a hypothetical example comparing the allocations of the first zone (zone 1) in the zonal sequence located at the north end of the Golden Gate Bridge in Marin County with the last zone (zone 440) located in San Francisco at the south end of the Golden Gate Bridge.

Employment allocations from zone 1 are distributed to those zones that have land available in sequential order from zone 1 to zone 440. If the allocation to these destination zones fills up the available land, and an excess occurs, then the overflow is reallocated to the nearest zone with land available. Employment allocations from zones 2, 3, 4, etc. to 440 are carried out in the same fashion, gradually filling up the destination zones. Note that the zonal capacities will be reached first from allocations in the lower range of zonal numbers. Thus, when the allocation from zone 440 is executed, many of the zones have reached capacity from the prior allocations in the zonal sequence. But now consider the overflows. These also are reallocated to nearby zones in the same range of zonal numbers. More low number zones are filled up. Fewer and fewer zones are available to accept the allocations or overflows when zone 440 employment is allocated. The distortion occurs

when some of zone 440's allocation goes, for example, to zone 300 (in Santa Clara County) and, because adjoining zones are completely full, the overflow cannot be placed in a destination nearer than some outlying zone, say 65 (Solano County), where a large amount of residential vacant land occurs.

When trips are composed connecting these zones, the allocation from zone 440 to zone 300 is reallocated to a distant northeasterly zone--a farfetched representation of commuter preference. This example has been purposely distorted to make clear the process, but instances have occurred in actual computer runs that are approximately as unreal.

Tests of alternative solutions should be made including (1) selecting a renumbered starting point for the zonal sequence; (2) partitioning the zonal allocations into three or four tiers, each consisting of equal proportions of allocable employment which add up to 100 per cent, and allocating each tier seperately; (3) constraining the length of the commuting trip to substantially less than the presently used 90 minute limit so that the work-to-home allocation more closely approximates the core of the commuter shed that serves the employment center.

Recalibration of model algorithms. Internal to the PLUM program are several regression submodels that enhance and amplify the variety of output variables that are useful in the planning context. Their abandonment was based on the need for model operation under severe time constraints and substitute algorithms were, in some cases, emplaced in the model in crude form. The submodels include (1) zonal family income levels and distribution, (2) structure type disaggregation, (3) streets and highways acreage absorption, and (4) zonal residential densities (lotsizes).

In several cases, the partitioning of land available for development under new definitions invalidated the coefficients used with the previous land concepts. Recalibration to the new definitions could be done with little difficulty.

The structure type disaggregation is based on nine observations, but should be enlarged to encompass jurisdictions, zones, or census tracts. This would reinforce the accuracy of the model and permit modification of the oversimplified conceptual basis now used. The density (lot size) model, when recalibrated, would allow evaluative comparisons between historical experience and local policy.

Updating the data base with the 1980 Census Data. The 1980 Censuses of Population and Housing will begin to be available after January 1, 1981. Preparations for the use of these data should be started now, so that related non-census variables can be estimated and allocated for comparable geographic units and time periods.

Data from the Census can be used for three major perposes: (1) to test the operation of the modeling system for its projective reliability; (2) to establish a new data base from which projection into the future can be made; (3) to establish a revised set of parameters and coefficients which control important relationships in the modeling system.

With regard to (1) testing forecasting reliability, the modeling system may be set up to forecast from 1970, or even from 1965, and projections under varying assumptions could be matched with 1980 census counts for counties, cities, and zones. The ultimate purpose for these tests would be to recalibrate the model to reflect the 1980 conditions.

The major programs to update the data base involve (1) collecting relevant land use data, augmented by square footage of structures; (2) estimating employment by place of work. These are programs that can be designed with varying degrees of completeness, depending on the resources in personnel and cost that are dedicated to the project.

The process complementary to the updating of the data base is a recalibration of the coefficients and parameters in the present system that are calculated on the basis of 1970 or 1975 censuses. These include zone-specific labor force participation rates, residential, commercial, and industrial land absorption coefficients, household sizes, and housing structure-types.

Another aspect of the 1980 data update is the establishment of a revised zonal system. Such a revision would also involve revision and modification of the time-distance matrices for interzonal auto and transit times, and reestimation of the trip tables for the new zonal system.

## SUGGESTED SEQUENCE OF REVISIONS TO THE MODELING SYSTEM

There are three levels of projected work that should be considered on the basis of this critique. First is the set of repairs that are virtually mandatory in the immediate future. Second are those that should be done further into the future either because they would take more time, or because they are postponable. Finally, there is a third category that requires a formalized work program with extra staff and resources to implement. The items below are classified into these categories as an aid to setting priorities.

### Immediate Modifications to the Modeling System

Recent experience with the modeling system provides the basis for some immediate modifications to the PLUM program. These involve:

(1) Changing the residential land absorption sequence. In effect, the program should be revised so that the new worker increment is allocated only to prime land across all zones. Then, if more land is required (i.e., overflows occur in some zones), the allocation should continue on secondary land. If overflows still occur after the allocation to secondary land, then these overflows should be allocated to remaining zones with prime vacant land, followed by overflows to secondary vacant.

(2) Testing and implementing alternatives to the problems raised by the zonal numbering sequence. This not only involves the land absorption sequence in (1) above but also fills the northern part of the region first, before Santa Clara, San Mateo, and San Francisco allocations occur. This distorts the spatial arrangement of allocations and the implicit trip table.

(3) Revising the local-serving algorithm. The structure of this submodel is in undocumentaed disarray. Although the focus has been on local-serving land absorption in recent runs for Projections '79, the employment allocations for this model sector needs to be assessed and retuning or more drastic surgery needs to be undertaken.

## Short-Range Future Modifications

The following modifications to the system involve a greater degree of commitment of resources, including some major programming, testing, data revision, and documentation. Therefore, their implementation requires a longer time-horizon although their importance is substantial and the prospective payoff in terms of model operation and validity is worthwhile.

(1) The two-tier allocation system involves the identification of a new set of subregional areas larger than the present zonal system. Along with this, the time-distance matrices have to be adapted to this zonal system. Third, allocations within the subregional areas have to be modeled in some consistent process to provide small-area data when that is required.

(2) The regression programs built into PLUM should be reevaluated for their potential usefulness and those considered necessary should be recalibrated to the definitions of variables now being used, particularly those involving land use concepts.

## Long-term Improvements

When a longer range program of system revision and improvement is organized, the following major building blocks of the system merit intensive review and replacement.

(1) The BEMOD conceptual framework and allocation program has always been the most inflexible, mysterious as to its mode of operation, difficult to reprogram, and sketchy in documentation. With current interest in ABAG being focused on economic development, this whole framework of modeling support should be scheduled for a long-term effort to ameliorate the apparent shortcomings of the allocation process and its interaction with the other models.

Of highest priority is the incorporation of labor force availability, possibly with designated skill and occupational levels, as an augmentation to the locational forces guiding the allocation of base employment.

(2) The regional econometric model needs to interact with the demographic model in order to constitute a "drive mechanism" for the regional system. Designing and calibrating a substantially revised regional economic model is necessary to reverse the operational inflexibility that presently exists and fill the void in documentation. Particular care in this work must be directed toward unique characteristics of the region, which should affect calibration to regional data as well as the makeup of the structure of industry. This exercise in design, although comprehensive, should be focused on high technology industries, major energy-providing and energy-using industries, office industries, retail trade and service industries, and the government sector partitioned into federal, state, local and public educational components.

(3) The overriding importance of office employment, carrying out the emphasis that emerged from the Economic Profile, should also be emphasized in the modeling system. This will require innovations in system design if the office industry is to be allocated directly instead of in a secondary and indirect manner as is now implemented implicitly. An important part of this model revision is the systematic treatment of central city headquarters activities, and the potential dispersion of these activities as a response to high land values, labor costs, and labor supply.

(4) The comprehensive revision of the data base to reflect the known state of the region in 1980 is no trivial task. Preparations for this are warranted immediately with definition of a work program and commitment of personnel. One of the most valuable resources in ABAG has been the regionally uniform data base, and this treasure should be protected and maintained. The major resource to be incorporated into the data base is the whole range of information from the 1980 Census of Population and Housing. In addition, another attempt to organize the journey-to-work data into employment files should be undertaken. The whole framework of land use categorizations is a unique and valuable data source that ABAG has contributed with cooperation from local jurisdictions and other sources, and this should be updated as part of this exercise. Finally, the commuter and time-distance (skim-tree) matrices which MTC has provided in the past should be reworked, especially if the two-tier system of model operation is adopted.

(5) Socio-economic disaggregation and land use/transportation interaction are both related to the modifications that have been developed by Putman at Pennsylvania. These can be put into the system by direct replacement of PLUM by ITLUP (Interactive Transportation Land Use Program) or the concepts can be used as the basis for a design that is more closely related to the system framework as it now operates. Additionally, Putman has developed a complex and sophisticated calibration procedure for establishing the parameters of his allocation functions. The adoption of his models and procedures would be a large step upward in the modeling state-of-the-art and would require a wholehearted commitment to a long shakedown period.

## DOCUMENTARY RESOURCES AVAILABLE FOR SUGGESTED REVISIONS

A continuing program of modifications and improvements to PLUM-type models has been in operation at the University of Pennsylvania under the direction of Professor Stephen Putman. He has developed models for base employment allocation, for interactive land-use/transportation projection, and income disaggregation. At one time, CalTrans was considering the replacement of his modeling system on its computer network allowing access by terminal from any connecting location in the state. A rich base for several of the suggestions contained here can be tapped from these sources.

A system operating in parallel with most of the same models as the ABAG system is at the San Diego Comprehensive Planning Organization (CPO). Although the technical people who have run the system in the past have left the organization, there may be a large catalog of in-house documentation that could be used to guide decisions about large scale changes.

Still another source of assistance is the comprehensive file of working papers developed at the Delaware Valley Regional Planning Commission (DVRPC) also located in Philadelphia. (Chin Ming Yang, who worked at DVRPC before he came to ABAG, has a substantially complete file of these.)

Finally, there are files of working papers that documented the activities of the team that developed PLUM at the Bay Area Transportation Commission (BATSC), that engineered further improvements at the University of California Institute of Transportation and Traffic Engineering (ITTE, now ITS), and that documented the operation of the system during the period 1972-77 at ABAG in collaboration with MTC. An almost complete collection of these papers is in possession of this writer.